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Utilizing legume-cereal intercropping for increasing self-sufficiency on organic farms in feed for monogastric animals

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Abstract. In 2009, controlled field trials were conducted on three certified organic farms with field pea (leaf type), spring barley and spring wheat in monocultures and mixtures (pea:cereal ratio 60:40) to study the possibility of producing fodder for monogastric animals under Czech conditions. By grain harvest time, seed samples were collected and analysed for dry matter, ash, crude protein, fat and crude fiber, and content of organic matter and nitrogen-free extracts (NFE) were determined. Weed harrowing at various pea heights were included at one farm. Samples for analysis of tannins and trypsin-inhibitor activity (TIA) were taken from treatments with no weed harrowing (H0) and harrowings at 5 and 10 cm pea height (H2). Analyses of amino acids were conducted from H0-samples. To complement the data from the farm trials, samples of grains from treatments with the same pea and cereal varieties in plot trials conducted in 2008 and 2009 studying the effect of pea:cereal seed ratio and weed harrowing at various pea heights, were analysed.

In cereals, the crude protein content increased by intercropping with pea. This increase was compensated for by a decrease in NFE. Wheat and barley grown in mixtures with peas seemed to contain more methionine than cereals in monoculture, and there tends to be higher threonine content in intercropped barley compared with barley monoculture. This is positive for the nutrition of monogastric animals. There were no pronounced effects of intercropping on tannins or TIA or on the content of other analysed nutrients in the cereals. The chemical composition of peas was not significantly impacted by intercropping.

Key words: LCI, farm level field trials, pea, wheat, barley, crude protein

INTRODUCTION

Intercropping can be defined as the agricultural practice of growing two or more crops within the same space at the same time (Andrews & Kassam, 1976). The main reason for growing two or more plant species together is the increase in productivity per unit of land. Several authors have shown that over time, average dry matter (DM) yields are higher with intercropping than when each of the plant species in the mixture is grown as a monoculture (Vandermeer, 1989).

When legumes are included in a crop mixture, an extra benefit is improved soil fertility due to the legume species' fixation of biological nitrogen (N), and increased protein content of the cereal component (Jensen, 2006). For animal fodder, legume-cereal intercroppings (LCI) are of special interest. Such mixtures may be harvested both for green fodder and concentrates. Field pea (*Pisum sativum* L.) mixed with wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.) are the most relevant LCI crops for Czech conditions. Peas grown in pure stands have a high risk of lodging, especially the leafy varieties. Growing peas together with cereals may reduce the risk of lodging (Salawu et al., 2001).

Organic farming systems aim at 100% organic fodder for all farm animals and a high degree of self-sufficiency. Fodder production on the farm is a challenge, especially for animals demanding high quality concentrates for effective growth and production, such as monogastrics (pigs and poultry). Currently, Czech organic farmers mostly buy expensive organic protein rich concentrates from other countries. This option is not economically profitable and may have social and environmental negative aspects. Further, there is a risk of importing GM contaminated seeds, which are banned in organic farming. A lack of domestic organic concentrates may reduce the interest of Czech farmers into converting to certified organic production. Pig and poultry production are protein-demanding. One of the main obstacles for converting pig and poultry production to organic is the need for locally produced organic fodder with high concentration of energy and protein and the right composition of amino acids.

Cereal grains are the major energy source in both pig and poultry diets. Both wheat and barley are excellent feed: they are high in carbohydrates (starch), palatable, and highly digestible. However, they need to be balanced by other crops with a complementary composition of amino acids, as they are low, especially in lysine, compared with the requirements of pigs and poultry. Grain legumes are often combined with cereals in concentrates, and field pea is of special interest, as stated above.

Peas can be a viable source of both energy and protein, since the amino acid profile closely matches requirements for many poultry species. For laying hens, peas can provide up to 40% of the diet without severely affecting performance, but 10% is a more practical level, with equal performance. Broilers and turkeys can consume 20 to 30% field pea without affecting performance (Anderson et al., 2002).

Among the amino acids, methionine and cysteine are important for the feather production of poultry. Low dietary methionine contents can contribute to incidences of injurious feather pecking and cannibalism (Hughes & Duncan, 1972). Methionine is the first limiting amino acid for poultry, followed by cysteine, lysine and threonine.

Lysine is the first limiting amino acid for pigs; methionine is second. Threonine and tryptophan are also of special importance for pigs. Field peas are usually rich in lysine, but low in methionine and tryptophan, limiting their use in pig diets. Further, peas contain anti-nutritional substances like tannins, lectins (hemaglutinin) and trypsin inhibitors. This also limits the share of peas that can be used in pig diets, but peas may be included up to 15 % for starter pigs and sows, and can completely replace soybean meal in the last part of the growth period of slaughter pigs (University of Minnesota, 2002).

Production of legume-cereal intercrops for concentrates may increase the self-sufficiency of organic farms, provided that the concentrates have satisfactory protein content and quality. This may help the farmers to be more independent, offering more predictable and possibly lower prices for fodder. This will also reduce the current dependency on imported soybeans and (extracted) soya meal, both of which have a high risk of GMO contamination.

In the project A/CZ0046/1/0024 “Utilizing Legume Cereal Intercropping to Increase Self-sufficiency in Animal Feed and Maintain Soil Quality on Organic Farms in the Czech Republic” (2009–10), mixtures and monocultures of cereals and field peas were grown in plot experiments as well as on organic farms to study the possibility of producing animal fodder. The fodder characteristics and implications of LCI harvested as green matter for ruminants are discussed in a separate paper (Ponizil et al., submitted). The present paper will focus on the suitability of the produced grains as concentrates for monogastric animals under Czech conditions. We will discuss the quality of LCI harvested at grain ripening used as concentrates for monogastric animals, presenting nutritional characteristics of monocultures and seed mixtures.

MATERIALS AND METHODS

Protein quality (crude protein, amino acids) and anti-nutritional substances were analysed in fractionated samples (peas, cereals) of seeds from mixture and monoculture treatments after grain harvest. The treatments were monocultures and mixtures of field pea (variety Bohatyr), spring wheat (variety Sirael) and spring barley (variety Pribina). In 2009, large scale experiments were conducted with normal farm equipments on five organic farms, located at various sites in the Czech Republic (CR). Each experimental plot had a net size of 0.5 ha, with no replicates. Seeds were harvested on three farms (Table 1). Five treatments were compared: wheat monoculture (S100), barley monoculture (P100), field pea monoculture (B100), pea-wheat mixture (B60S40) and pea-barley mixture (B60P40). The pea:cereal ratio at seed planting was 60:40 (by weight), and the fields were harrowed once at pea height 5 cm. Grain harvest was done by the farmers, and a sample of about 3 kg of grain was taken from each treatment. On the Postrelmov farm, the experimental plots were divided in four blocks to test weed harrowing at various pea heights. Samples for analysis of the anti-nutritional substances tannins and trypsin inhibitor activity (TIA) were taken from treatments with no weed harrowing (H0) and two harrowings (H2), at 5 and 10 cm pea height. The size of each experimental plots was in this case 0.5/4 = 0.125 ha, and three samples of grains per plot were taken. Grains were dried by cold air circulation, and weeds removed before fractionating peas and cereals in the mixtures.

To complement the data from the farm trials, samples of grains from treatments with the same pea and cereal varieties in plot trials studying the effect of pea:cereal seed ratio and weed harrowing at various pea heights were analysed. The plot trials were located at the experimental fields of the company Agritec, Ltd. in Rapotin (RA) in district Sumperk in Central Moravia, conducted in 2008 and 2009. Samples were taken from the B60S40 and B60P40 treatments and the corresponding monocultures B100, S100 and P100. Samples for analysis of the anti-nutritional substances tannins and trypsin inhibitor activity (TIA) were taken from the weed harrowing plot trial from treatments with no weed harrowing (H0) and with two harrowings (H2), at 5 and 10 cm pea height.

Table 1. Field trials – Overview of production systems on the organic farms hosting the field experiment.

Farm Locality	Production system	Location	Altitude (m.a.s.)
BEMAGRO Inc. Malonty (MA)	Cash crops: Rye, spelt and winter wheat Animal production: Beef cattle, dairy cows	48°41'22"N, 14°35'6"E	690
BIOFARMA SASOV Sasov u Jihlavy (SA)	Cash crops: Potatoes, camelina, hemp, buckwheat Fodder crops: Legume-cereal mixtures(LCI) Animal production: Slaughter pigs, beef cattle Charolais	49°22'38"N, 15°36'8"E	525
EKOFARMA CECHOVI Postrelmov (PO)	Cash crops: Spelt, wheat, barley, spelt for seed production and grass seeds Fodder crops: LCI; Animal production: Beef sheep	49°54'51"N, 16°53'56"E	290

The experimental plots in the weed harrowing trial were randomized, within blocks of harrowing, with three replicates per treatment. In the seed ratio trial the size of each experimental plot was 13 m^2, and the plot harvest area was 10 m^2. In the weed harrowing trial the size of each experimental plot was 8.6 m^2, and the plot harvest area was 5.5 m^2. At grain harvest, an experimental combiner was used and all grains were sampled from each experimental plot. Grains were dried by cold air circulation and weighed, then impurities (mainly weeds) were removed and peas and cereals were fractionated. More information about the farm level and plot trials are found in Huňady et al. (submitted) and Ponizil et al. (submitted).

Amino acids were analysed in fractionated samples (peas, cereals) of seeds from mixture and monoculture treatments at the seed ratio trial at Rapotin and the weed harrowing trials at Postrelmov farm, but only in the H0 treatment. The anti-nutritional substances were only analysed in the weed harrowing treatments, to study the effect of weeds on the content of anti-nutritional substances (Table 2).

Chemical analysis

All samples were analysed for crude protein, etc. according to the stepwise Weenden-procedure (Tables 2 & 3). Additionally, amino acids were analysed in samples from the plot trials in Rapotin in 2008 and 2009 and Postrelmov in 2009 (Table 2). The following amino acids were determined by standard procedure BS EN ISO 13903:2005: Asparagine, threonine, serine, glutamine, proline, glycine, alanine, valine, cysteine, methionine, leucine, tyrosine, phenylalanine, histidine, lysine, and arginine. In this analysis, the amino acids are separated by ion exchange chromatography and determined by reaction with ninhydrin with photometric detection. For anti-nutritional substances, the concentration of tannins and trypsininhibitiors was analysed in samples from the harrowing trials at Rapotin and Postrelmov in 2009 (Table 2).

Table 2. Overview of samples, analyses and number of samples for each site.

Site	Weenden	Am. Acids	Antinutr.
Three organic farms	n=21	no	no
Rapotin, seed ratio trial 2008 and 2009	n =14	n=14	no
Rapotin, weed harrowing H0+H2, 2009	no	no	n=8
Postrelmov, weed harrowing H0+H2, 2009	no	n=7 (only H0)	n=18

For Weenden- and amino acid analyses, at each site, three monocultures and fractionated pea samples of the two mixtures were analysed at no weed harrowing H0 and two harrowings (H2), at 5 and 10 cm pea height. From the Postrelmov harrowing trial three samples from pea as monoculture and three fractionated pea samples of the two mixtures were analysed at H0 and H2.

Table 3. Weenden analysis, for evaluation of feed energy content, crude proteins, fat, fibre and N-free extracts.

Parameters	Method
Dry matter (DM)	Gravimetrically, drying at 105°C to constant weight, 2–5 hours (depending on humidity)
Ash (A)	Gravimetrically, annealing at 550°C, 3 hours to get a light ash (according to CSS 46 7092)
Organic matter (OM)	Mathematically, OM = DM – A
Crude protein (CP)	N concentration multiplied by 6.25, Kjeldahl method – mineralization in concentrated sulfuric acid, desilace, titration (Kjeltec 2200 Analyzer Unit)
Fat (F)	Ethyl ether extraction (gravimetry) (Soxtec system HT6 Tecator)
Crude fiber (CF)	Cooking 0.5 hours in 1.25 % sulfuric acid, 0.5 hours in 0.223 M NaOH, rinsing with water, drying in the oven, weighed, ignition (gravimetry) (FIBERTEC-1021)
Nitrogen-free extract	Mathematically, NFE = OM – CP – F – CF

The basis for calculating the metabolizable energy (MEp), feed allotments and feed mix composition is digestible nutrients, as measured by Weenden analysis (Table 3). The multiple regression equation expressed in MJ units (Hoffmann & Schliemann, 1980) has the following form:

$$\text{MEp (MJ)} = 0.0210\ \text{DCP} + 0.0374\ \text{DF} + 0.0144\ \text{DCF} + 0.0171\ \text{DNFE} - 0.0014\ \text{S}^{+}$$

DCP - digestive crude protein in g kg^{-1}
DF - digestive fat in g kg^{-1}
DCF - digestive crude fiber in g kg^{-1}
DNFE - digestive nitrogen free extract in g kg^{-1}
S - reducing sugars in g kg^{-1}

$^{+}$ correction for the sugar content is used for feed only when the content is greater than 80 g kg^{-1} of dry matter

The following relationship specified by Wissmann & Colle (1985) is used for calculating the MEp content in feed mixtures from the TDN (total digestible nutrients) content:
1 kg TDN = 17.57 MJ MEp
CP – crude protein
F – fat
CF – crude fiber
NFE – nitrogen free extract
OM – organic matter
A – ash
DM – dry matter

We did not establish the coefficients for the digestibility of individual nutrients; instead we used the values determined by Zeman et al. (1999) (Table 4).

Table 4. Nutrient Digestibility Coefficients (Zeman et al., 1999) of crude protein (CP), fat (F), crude fiber (CF) and nitrogen-free extract (NFE).

Grain	CP	F	CF	NFE
Pea	0.85	0.46	0.50	0.92
Barley	0.78	0.49	0.17	0.88
Wheat	0.85	0.70	0.29	0.92

Statistical analysis

Using the three farm level field experiments and the Rapotín 2008+2009 seed ratio trial as replicates, the statistical significance of differences between treatments in nutritional content and amino acids of grains were analysed by variance analysis (*GLM*). Statistically significant differences between treatments were assessed by *LSD* and *Tukey Simultaneous Test*, with software Minitab 15 (Minitab Inc., 2009). Contents of TIA and tannins are only presented as descriptive statistics. The mean value of the two samples of pea monoculture from the Rapotin weed trial was compared with samples of intercropped peas from Rapotin and the mean value of three samples from the other pea samples (pea monoculture and fractionated pea samples from the two mixtures with wheat and barley) from Postrelmov farm.

RESULTS AND DISCUSSION

The average results of the Weenden analysis for monocultures and fractionated mixtures, based on values of samples from the different sites and seasons as shown in Table 2, are shown in Table 5, and calculations of metabolizable energy are shown in Table 6.

Table 5. Results of the Weenden analysis for monocultures and fractionated mixtures.

		(g kg^{-1} of DM)				
Type	Treatment	Crude Protein	Fat	Crude Fat	NFE	Ash
Pea	Monoculture	228.8	11.3	70.4	650.2	39.3
		(19.8)	(1.1)	(10.3)	(31.6)	(10.6)
	+ wheat	228.6	11.5	70.3	651.2	38.5
		(14.2)	(1.3)	(5.5)	(22.4)	(14.9)
	+ barley	227.4	12.1	69.3	657.2	34.0
		(18.0)	(2.0)	(12.8)	(24.7)	(3.5)
wheat	Monoculture	133.5	20.2	34.5	786.9	24.8
		(11.5)	(1.9)	(7.4)	(22.0)	(8.4)
	+ pea	161.0	20.2	26.7	748.7	43.4
		(15.3)	(1.6)	(7.2)	(43.1)	(41.3)
barley	Monoculture	116.6	17.6	46.3	789.2	30.3
		(18.2)	(1.7)	(4.9)	(28.5)	(11.5)
	+ pea	144.9	19.0	55.4	748.5	32.2
		(15.6)	(1.9)	(11.5)	(22.2)	(8.3)

Three farms Malonty, Sasov, Polstrelmov (n = 21) and seed ratio trial at Rapotin in 2008 and 2009 (n = 14). Every value is a mean of the five locations. Standard deviation (std) values are shown in brackets under every average.

In cereals, intercropping increased the content of crude protein significantly. In comparison to cereal monoculture, wheat grown in the mixture with peas contained 27.5 g extra CP kg^{-1} of DM, and barley contained 28.3 g extra CP kg^{-1} DM ($P<0.05$, Fig. 1). The crude protein content of peas was not influenced by intercropping (Fig. 1). This result is well in line with Jensen 2006. The CP content in the samples of monocultures and fractionated samples from pea-cereal mixtures was dependent on site and year (Higher CP content at Malonty and Rapotín in 2008 than at Rapotínin 2009; $P<0.05$).

No significant effects were found of intercropping on the content of fat, ash or metabolizable energy, but there was a large variability in the results, with significant differences between sites and years.

Table 6. Calculated metabolizable energy of samples from monocultures and fractionated mixtures.

Type	Treatment	g kg^{-1} DM org. matter	digestibility coefficient Crude Protein	Fat	Crude Fibre	NFE	ME p (g kg^{-1} DM)
pea	Monoculture	960.7 (10.6)	0.9	0.5	0.5	0.9	15.0 (0.2)
	+ wheat	961.5 (14.9)	0.9	0.5	0.5	0.9	15.0 (0.3)
	+ barley	966.0 (3.5)	0.9	0.5	0.5	0.9	15.1 (0.1)
wheat	Monoculture	975.2 (8.4)	0.9	0.6	0.4	0.9	15.4 (0.2)
	+ pea	956.6 (41.3)	0.9	0.6	0.4	0.9	15.2 (0.7)
barley	Monoculture	969.7 (11.5)	0.8	0.5	0.3	0.9	14.6 (0.4)
	+ pea	967.8 (8.3)	0.8	0.5	0.3	0.9	14.5 (0.5)

Three farms Malonty, Sasov, Polstrelmov (n = 21) and seed ratio trial at Rapotin in 2008 and 2009 (n = 14). Every value is a mean of the five locations. Standard deviation (std) values are shown in brackets under every average.

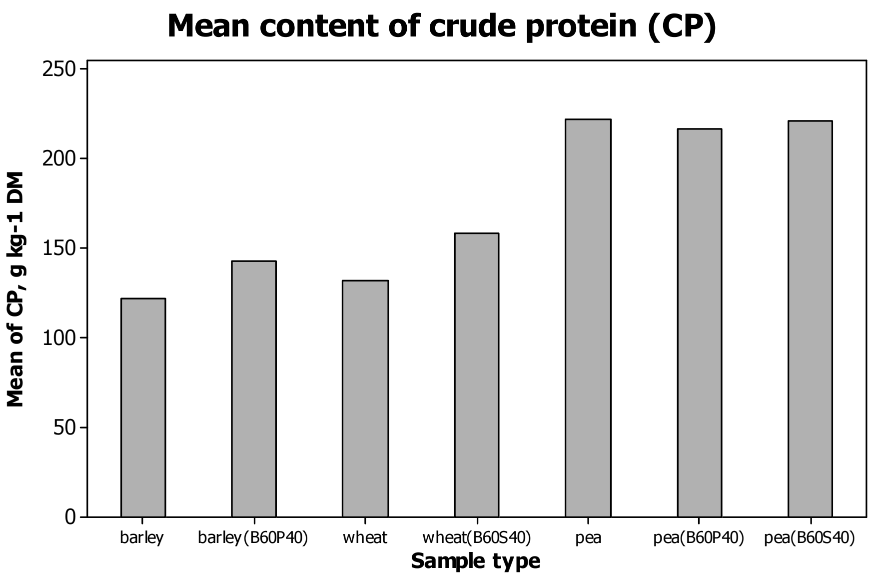

Figure 1. Mean content of crude protein (CP) in seeds of pea, barley and wheat grown as monocultures or in fractionated samples from pea-cereal mixtures.

Data are mean values from three organic farms Malonty, Sasov and Postrelmov in 2009, and a seed ratio trial in Rapotín in 2008 and 2009 (n = 5). The sample types are barley (variety Pribina (P)), wheat (variety Sirael (S)) and pea (variety Bohatyr (B)) as monocultures and fractionated samples of barley (pea 60% and barley 40% – Barley (B60P40)), wheat (pea 60% and wheat 40% – Wheat (B60S40)), pea (pea 60% and barley 40% – Barley (B60P40) and pea 60% and barley 40% – Barley (B60P40)).

There was a tendency of lower NFE content in barley (*P = 0.07*) and wheat (*P = 0.10*) grown as intercrops compared with monoculture. We recorded a decrease in mean NFE content at the three localities of 38 g kg^{-1} DM from monoculture to intercropped wheat and about 41 g kg^{-1} of DM from monoculture to intercropped barley. MEp was somewhat higher in wheat than pea and barley monocrops and fractionated intercrops (Table 6).

The average amino acid concentrations in the analysed samples are shown in Table 7. In most cases, intercropping increased the amino acid concentrations in the cereals, whereas the effect of intercropping on the amino acid concentrations in the peas was negligible.

Table 7. Amino acid concentration in seeds of pea, barley and wheat grown as monocultures or in pea-cereal mixtures.

	Pea			Wheat		Barley	
	Mono-culture	+ wheat	+ barley	Mono-culture	+ pea	Mono-culture	+ pea
Asp	19.8	20.3	20.2	6.7	7.4	6.2	4.0
Thr	6.3	6.6	6.5	3.7	3.8	3.4	4.0
Ser	7.6	7.8	7.9	5.5	5.7	4.2	4.9
Glu	26.8	27.6	27.5	32.2	34.5	21.9	27.0
Pro	6.6	7.5	7.6	13.5	11.6	12.7	14.4
Gly	8.3	8.3	8.2	5.3	5.8	4.2	5.0
Ala	6.9	7.3	7.2	4.2	4.1	4.1	4.6
Val	8.2	8.1	8.2	5.6	4.7	5.2	5.6
CysH	2.0	2.1	1.9	1.8	2.2	1.7	1.8
MetS	1.5	1.6	1.5	1.4	1.6	1.5	1.7
Ile	7.3	7.5	7.2	4.2	4.1	3.5	3.8
Leu	13.0	13.2	13.1	8.2	8.7	7.1	8.2
Tyr	4.8	4.9	5.0	3.0	3.2	3.0	3.4
Phe	8.7	8.9	8,9	5.6	6.1	5.6	6.6
His	4.6	4.6	4.5	2.9	3.3	2.4	3.0
Lys	13.5	13.7	13.5	4.0	4.2	4.2	5.0
Arg	15.7	15.3	15.3	7.0	7.1	5.7	6.9

Postrelmov farm in 2009 (n = 7) and at Rapotín in 2008 and 2009 (n = 14). The results are presented as mean of the three localities. The amino acids are presented in g kg^{-1} DM.

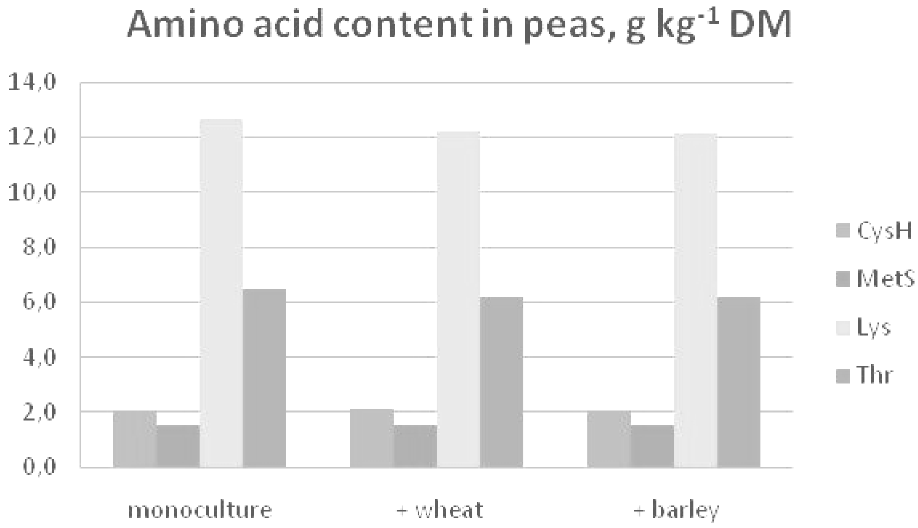

Figure 2. Mean content of cysteine, methionine, lysine and threonine in peas as monoculture or intercropped with wheat or barley, from the Postrelmov farm in 2009 and Rapotín farm in 2008 and 2009.

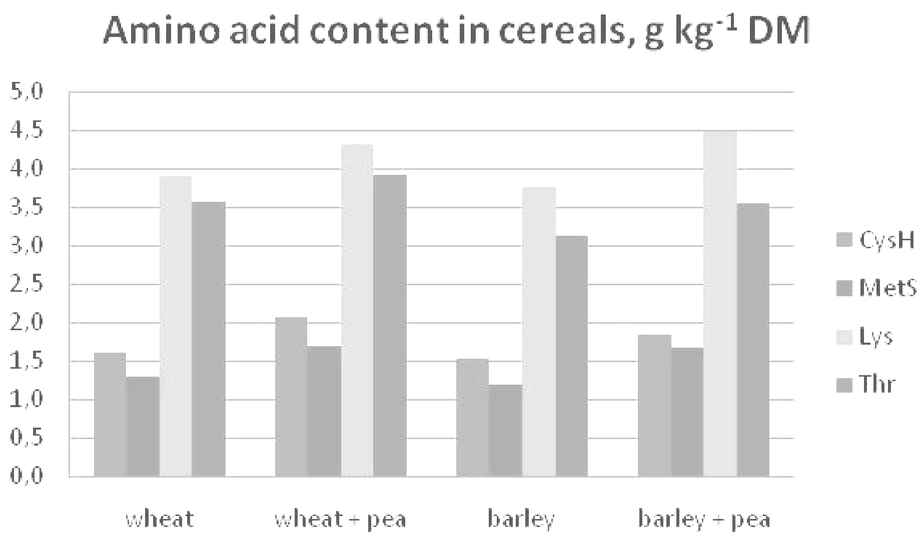

Figure 3. Mean content of cysteine, methionine, lysine and threonine in wheat and barley as monocultures or intercropped with pea, from the Postrelmov farm in 2009 and Rapotín farm in 2008 and 2009.

The concentrations of the four amino acids with the largest impact on the fodder`s suitability as pig and poultry feed are shown in Figs 2 & 3. There were no statistically significant effects of intercropping on the amino acids content in seeds of pea, barley and wheat grown as monocultures or in pea-cereal mixtures. Figures of the four most important amino acids for pig and poultry feed show slightly higher threonine content in intercropped barley compared with barley monoculture, and a tendency of higher methionine content in cereals when intercropped with pea (Table 7 & Fig. 3).

Šimeček et al. (1993) list the content of lysine in peas at 14.7 g kg^{-1} DM, while wheat has 3.1 g kg^{-1} DM and barley 3.9 g kg^{-1} DM. Our values for lysine are lower than these values for pea monoculture and higher for monocultures of wheat and barley, and values for intercropped wheat and barley seem to be even higher than values in monocultures (Fig. 3). The lysine content varied between sites and years ($P<0.01$), with highest content in Rapotín in 2008 and lowest in Postrelmov. The content of threonine also varied among the three localities ($P<0.005$), with highest content in Rapotín in 2008.

Growth conditions can influence the TIA in pea (Leterme et al., 1990). We wanted to see if the plants were producing more anti-nutritional substances when stressed by competition with weeds. Harrowing did not seem to affect the tannin content or the content of TIA in the samples, despite more weeds in the non- harrowing field plots, with creeping thistle (*Circium arvense L.)* as the dominating weed. For all analysed samples the mean content of tannins was 1.16% with a standard deviation (*st.dev*) of 0.24 (n = 12) and of TIA 6.21% with a *st.dev* of 1.51 (n = 12). The tannin content did not vary much among the sites, except a very high level in peas from the pea-wheat mixture with two harrowings at the Postrelmov farm (1.83%). The TIA-content was generally higher at Rapotín (mean content, 7.18%, n = 6, *st.dev* 0.7) than at Postrelmov (mean content, 5.25%, n = 6, *st.dev* 1.49).

The amino acid composition in a feed ration for slaughter pigs, with 40% wheat or barley and 60% pea, grown as intercrop, will not be sufficient compared with the ideal protein content for pigs (Table 8). The content of threonine, cysteine, methionine, isoleusine and tyrosine is too low compared with the ideal protein content for pigs' maintenance. Methionine can meet the total need for sulphur amino acids in the absence of cysteine. The amino acid content in the feed ration with wheat had slightly higher ratios of several of the amino acids to lysine, but was still too low. The lysine content in the two feed ratios was quite similar, with 8.9 g kg^{-1} in pea-wheat ration and 9.0 g kg^{-1} in pea-barley ration. A feed ration for laying hens with 40% pea and 60% cereal from the intercropped mixtures will give 7.1 g kg^{-1} lysine and 1.4 g kg^{-1} in pea-wheat ration and 7.5 g kg^{-1} and 1.5 g kg^{-1} in pea-barley ration. These rations are deficient in lysine and methionine compared with a target minimum of 8.6 g kg^{-1} lysine and of 4.1 g kg^{-1} methionine (Gordon, 2005).

Table 8. Ratios of amino acids to lysine in feed rations of pea and wheat or pea and barley from intercrops (60% pea and 40% cereal), and ideal ratios of amino acids to lysine for maintenance, protein accretion, milk synthesis, and body tissue in pig.

	Intercropped rations		Ideal protein[1]			
Amino acids	pea/wheat	pea/barley	Maintenancea	Protein Accretionb	Milk Synthesisc	Body Tissued
Lys	100	100	100	100	100	100
Arg	121.3	118.2	-200	48	66	105
Thr	55.2	54.5	151	60	58	58
CysH	21.1	18.4	[2]123	[2]55	[2]45	[2]45
MetS	16.2	15.7	28	27	26	27
Ile	61.9	58.0	75	54	55	50
Leu	114.8	110.0	70	102	115	109
Tyr	42.5	43.0	[3]121	[3]93	[3]112	[3]103
Phe	78.3	78.9	50	60	55	60
His	41.2	38.8	32	32	40	45

[1] Subcommittee on Swine Nutrition et al. (1998)
[2] Methionine + cystein
[3] Phenylalanin + tyrosine

To meet the need for different amino acids, a feed ration based only on pea and barley or wheat, grown as intercrops, presume a high feed intake, and overfeeding with protein. This is both expensive, inefficient and causes a risk of nitrogen pollution when the manure is applied on land. Maize gluten is rich in sulphur-containing amino acids and is lower in lysine than the pea and cereal mixtures, and might therefore complement the pea-cereal ration, but it is probably difficult to get organic produced maize gluten. There is a need for organic sources of methionine-rich ingredients for organic feeding of poultry and pig.

CONCLUSIONS

The trials with legume cereal intercropping, supplemented with results from a two year plot trial, indicate that the crude protein content and concentrations of some amino acids in cereals are increased when the cereals are intercropped with field peas. However, the increase is compensated for by a decrease in NFE. We did not record any pronounced effects of intercropping on other recorded nutrients. Intercropping had no significant effects on the chemical composition of pea seed. For monogastric animals, the concentrations of the amino acids lysine, threonine, methionine, and cysteine are most important, as cereals tend to contain too little of these to fulfil the demands. Intercropping tends to increase the concentrations of methionine and threonine in the cereals, and the concentrations in peas were not influenced by intercropping. Hence, legume-cereal intercropping may produce more suitable fodder for monogastric animals than monocultures of cereals mixed with peas. Rations based on pea and wheat or barley (from intercrops) do not fully meet the requirement for different amino acids for monogastric animal and should be supplemented with a methionine-rich ingredient to avoid over-feeding with protein.

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REFERENCES

Anderson, V. (ed.), Harrold, R., Landblom, D., Lardy, G., Schatz, B. & Schroeder, J. W. A guide to feeding field peas to livestock. Nutrient content and feeding recommendations for beef, dairy, sheep, swine and poultry. AS-1224. North Dakota State University. http://www.ag.ndsu.edu/pubs/ansci/livestoc/as1224w.htm

Andrews, D. J. & Kassam A. H. 1976. The importance of multiple cropping in increasing world food supplies. pp. 1–10 in R. I. Papendick, A. Sanchez, G. B. Triplett (Eds.), *Multiple Cropping*. ASA Special Publication 27. American Society of Agronomy, Madison, WI.

Subcommittee on Swine Nutrition, Committee on Animal Nutrition, Board on Agriculture, National Research Council 1998. Nutrient Requirements of Swine: 10th Revised Edition. NATIONAL ACADEMY PRESS 2101 Constitution Avenue, NW Washington, D.C. 20418.

Gordon, S. 2005. *Validation of the HEN model for organic laying hens and assessment of nutrition in organic poultry (CTE0202)*. Rothamsted Research, Harpenden, Herts., AL5 2JQ, UK, 25 pp.

Hoffmann, L. & Schiemann, R. 1980. Von der Kalorie Zum Joule: Neue Grössebeziehungen bei Messugen des Energie umsatzes und bei der Berechnung von Kennzahlen der energetischen Futterbewertung. *Arch. Tierernährung* **30**,733–742.

Hughes, B. O. & Duncan, I.J.H. 1972. The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *Br Poult Sci* **13**, 525–547.

Jensen, E. S. (ed) 2006. INTERCROP-final report, Risø, Danmark, 303 pp.

Leterme, P., Beckers, Y. & Thewis, A. 1990. Trypsin inhibitors in peas: Varietal effect and influence on digestibility of crude protein by growing pigs. Animal Feed Science and Technology **29**(1–2), 45–55.

Minitab Inc. 2009. *Minitab 15. Pack of statistic software with an easy-to-use interface*. Mindows. http://minitab.en.malavida.com/

Pozdíšek, J., Henriksen, B. & Ponížil, A. 2010. Utilizing Legume-Cereal Intercropping to Intensify Self-sufficient Organic Animal Production Systems. Cattle research **3**, 44–57.

Salawu, M. B., Adesogan, A. T., Weston, C. N. & Williams, S. P. 2001. Dry matter yield and nutritive value of pea/wheat bi-crops differing in maturity at harvest, pea to wheat ratio and pea variety. *Animal Feed Science and Technology* **94**, 77−87.

Šimeč, K., Zeman, L. & Heger, J. 1999. *Potřeba živin a tabulky výživné hodnoty krmiv pro prasata (Nutrition Needs and Nutrition Value Tables for Pig Feed)*. ČAZV, The Commission of Farm Animal Nutrition. VÚVZ Pohořelice 1999, 78pp.

University of Minesota 2002. Challenges in Feeding Organically Raised Pigs. BU-07736. http://www.extension.umn.edu/distribution/livestocksystems/components/7736c03.html

Vandermeer, J. 1989. *The Ecology of Intercropping*. Cambridge University Press, New York. 237 pp.

Wissmann, J & Cole, D. J. A. 1985. O*n Recent Developments in Pig Nutrition*. Eds. Cole, D. J. A. & Haresign, W. Butterworths, London, pp. 60–72.

Zeman, L. et. al., 1999. *Katalog krmiv (Feed Catalog)*. ČAZV, The Commission of Farm Animal Nutrition. VÚVZ Pohořelice, 465 pp.